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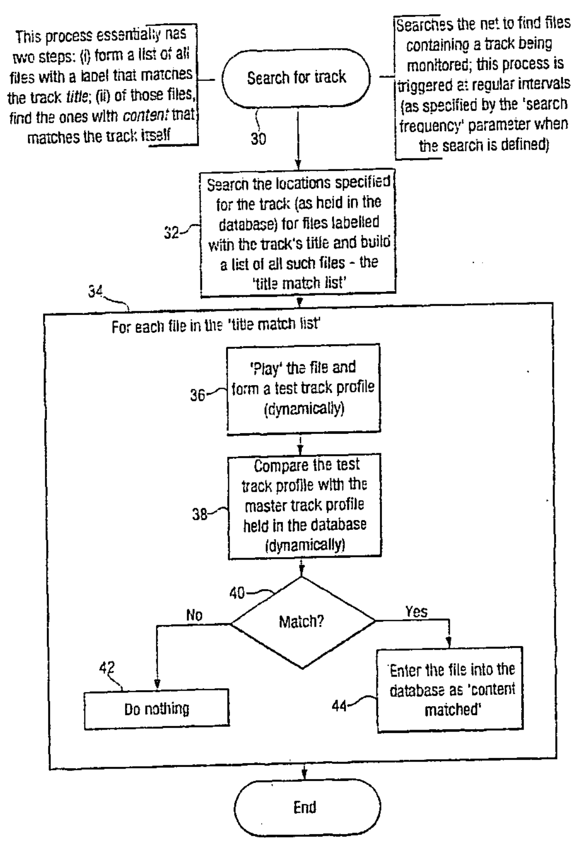
(54) Title: METHOD AND APPARATUS FOR IDENTIFYING ELECTRONIC FILES



(57) Abstract: The invention provides a method and apparatus for identifying electronic files under test. According to the invention, this process of identification involves reading a master file including a master signal sequence, dividing the master signal sequence into segments, generating a reference indicator representing each master signal segment, storing the respective reference indicators as a master profile, reading a test file including a test signal sequence, dividing the test signal sequence into segments, generating respective test indicators for successive segments of the test signal sequence to form a test profile, comparing the reference indicators and the test indicators successively for respective corresponding segments of the master and the test signal sequences, determining whether the reference indicators and the test indicators match, and generating a corresponding indication.

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METHOD AND APPARATUS FOR IDENTIFYING ELECTRONIC FILES

This invention concerns a method and apparatus for identifying electronic files, particularly electronic files containing audio information. The invention has particular application in the identification of unknown audio files by matching such files with a master audio file.

It is envisaged that the invention will be employed for searching for particular audio files and audio tracks on the Internet and for checking whether the audio files or tracks which are located match a master audio track whose details are stored in a database.

It is already known to search for particular audio tracks on the Internet and to identify the tracks which are located by employing a person to play back the tracks which are located and to identify them by ear.

It is also known to store the title of a particular track in a database and to search the Internet for corresponding titles. Titles located in the search are compared with the title held in the database and, if there is a match, an assumption is made that the corresponding audio tracks also match. The drawback with this is that the actual audio tracks themselves are not compared and so the matching of tracks cannot be verified and the identification of untitled tracks is not possible. Consequently, the accuracy of such an arrangement leaves something to be desired.

Another known process takes the content of a particular audio track and subjects this in a computer or data processing apparatus to an algorithm which

generates a code representing that track. This code is stored in a database of the computer. It is then possible to search the Internet for corresponding audio tracks by locating unknown tracks, subjecting them to the same algorithm to generate identification codes, and comparing such identification codes with the code in the database file to establish whether or not they match. However, such a process does not fully address a central problem of audio file matching, namely the fact that two files containing the same audio track need not contain precisely the same binary pattern. There may be differences caused, for example, by recordings originating from different sources, or starting at different points in time, or containing noise spikes or background noise. Given these differences, and depending on the precise coding algorithm employed, the code generation approach either generates spurious matches or fails to identify genuine matches. So the overall accuracy of the identification process is poor.

The present invention seeks to overcome the above problems and to provide a method and apparatus for reliably, accurately and rapidly identifying electronic files.

According to one aspect of the present invention, there is provided a method for identifying electronic files under test, the method comprising the steps of:

reading a master file including a master signal sequence,
dividing the master signal sequence into segments,
generating a reference indicator representing each master signal segment,
storing the respective reference indicators as a master profile,
reading a test file including a test signal sequence for comparison,
dividing the test signal sequence into segments,

generating respective test indicators for successive segments of the test signal sequence to form a test profile,

comparing the reference and test indicators successively for respective corresponding segments of the master and the test signal sequences,

determining whether the reference and the test indicators match, and generating a corresponding indication.

According to another aspect of the present invention, there is provided apparatus for identifying electronic files under test, the apparatus comprising:

means for reading a master file including a master signal sequence,

means for dividing the master signal sequence into segments,

means for generating a reference indicator representing each master signal segment,

a store for storing the respective reference indicators as a master profile,

means for reading a test file including a test signal sequence for comparison,

means for dividing the test signal sequence into segments,

means for generating respective test indicators for successive segments of the test signal sequence to form a test profile,

means for comparing the reference and test indicators successively for respective corresponding segments of the master and the test signal sequences,

means for determining whether the reference and the test indicators match, and

means for outputting a corresponding indication.

In a preferred form of the invention, the master signal and the test signal both comprise audio signals. For example, the master signal may represent a popular song or a track from a popular album, and the invention may be employed to check whether the test signal constitutes the same song or track.

Preferably, the master and the test signal sequences are taken from digitally encoded audio tracks.

Preferably, each indicator is a simple value representing a distinguishing characteristic of the waveform, such as its dominant frequency in the respective segment. For example, the indicators may be generated by determining one of a zero crossing count or another dominant frequency value for the audio signal portion included in each segment.

Advantageously, the method or apparatus according to the invention is arranged to generate a plurality of profiles for a respective file by:

creating a first set of segments commencing from a first predetermined point of the signal sequence for generating a profile,

shifting the first predetermined point by a predetermined amount to a new predetermined point of the signal sequence, and

creating a new set of segments commencing from the new predetermined point to form another profile.

The invention is described further, by way of example, with reference to the accompanying drawings in which:

Figures 1 to 3 are flowcharts generally representing a process according to the present invention;

Figure 4 is a waveform diagram representing the digital encoding of an analogue waveform such as a master audio track;

Figure 5 is a waveform diagram showing the comparison of a master waveform with two test waveforms;

Figure 6 is a waveform diagram further illustrating the comparison of a test waveform with the master waveform;

Figure 7 is a waveform diagram showing a segment of the test waveform and showing how segment shifting is effected for comparison purposes;

Figure 8 is a flowchart representing the generation of a master file according to the present invention;

Figure 9 is a flowchart representing a sub routine in the generation of the master file according to Figure 8;

Figure 10 is a flowchart representing the comparison of a test file with the master file according to the present invention;

Figure 11 is a flowchart representing the step of forming a test profile according to the present invention;

Figure 12 is a flowchart representing a sub routine in the process of forming a test profile shown in Figure 11;

Figure 13 is a flowchart representing an optimised file matching process according to the present invention; and

Figures 14-16 are flowcharts representing sub routines of the optimised file matching process shown in Figure 13.

The invention as described herein is applied to the identification and matching of audio tracks. For example, such tracks may be popular songs, tracks from

popular albums, or tracks from classical or other music recordings. They may also be tracks from voice recordings or other audio performances.

The invention will be described generally first with reference to Figures 1-3.

Figure 1 shows a flowchart representing the steps involved in generating a master or reference file in the database for implementing the present invention. Firstly, in step 10 a computer operator selects a new title and the corresponding audio track for entry into the computer database. The operator inputs the title text to the computer in step 12 and the computer captures this text as a name for a master file to be generated subsequently. In step 14, the computer receives the track corresponding to the title and generates a master file containing a track profile representing the track. The title and the master file are stored in a database of the computer in step 16 for subsequent processing.

Turning now to Figure 2, when a search is requested for tracks matching the new master track entered into the computer in Figure 1, the computer operator formulates a search definition in step 20 identifying the title and the possible locations to be searched. In step 22, the operator enters search information into the computer including the title, the location or locations to be searched, and possibly the frequency at which searching is to be carried out. Such information is stored in the database in step 24 for subsequent use.

Figure 3 shows a flowchart representing an actual search, as follows. The search is initiated in step 30, and the computer accesses the database for the details stored in step 24 of Figure 2. In step 32, the computer performs a two-step operation, first searching the locations specified in step 24 for tracks

having the specified title and secondly building up a list of test files containing tracks whose titles match. Next, in step 34, the computer checks each test file for the various tracks located. This involves dynamically forming a test track profile in step 36, followed in step 38 by dynamically comparing the test profile with the master profile already stored in the database in step 24. The outcome of the comparison is noted in step 40 and, if no match is found, the computer does nothing as shown in step 42. On the other hand, if a match is found, the computer proceeds to step 44 and enters into the database a flag or marker to indicate that a match has been found.

It will be appreciated that, although the steps described with reference to Figures 1-3 refer to a single master file and a single test file, in practice the database will store a number of master files and may be searching concurrently for matches for various different master files and may also be checking concurrently plural test files against each master file.

Turning to Figure 4, the process of forming a master profile and a test profile will be described in greater detail. Figure 4 represents an analogue waveform 50 corresponding with the audio sound recorded on a master track or an unknown test track as may be. In practice, the analogue audio signal will probably have been recorded in digitally encoded form by sampling the waveform many hundreds of times per second, sufficiently frequently to capture the highest frequency signal of interest in the waveform. At each sampling interval, the amplitude of the waveform is measured and encoded as a positive or negative number representing a single digital sample. This is indicated in Figure 4 by the stepped outline 52 to the waveform. By way of example, certain equally spaced sampling intervals 54 are shown in Figure 4 by dotted

lines, and the corresponding numbers marked. The sequence of numbers from successive sampling intervals provides the digital encoding for the waveform.

In order to generate a master profile for a master file or a test profile for a test file, the signal sequence is divided into fixed segments 56 of equal duration, typically 1/10 second, as shown in Figure 5. Referring to Figure 5, line (a) shows the analogue signal and corresponding profile for a master file and in lines (b) and (c) the analogue signals and corresponding profiles for two files to be tested. For each segment 56 of a particular track, the computer allocates a reference or test indicator representing the waveform in this segment 56. This indicator is a simple value representing a distinguishing characteristic of the waveform, such as its dominant frequency. In the present instance, the indicator is based on the zero crossing count for the waveform within that segment 56. More particularly, the computer detects the number of times that the waveform crosses the zero axis within the segment 56 and sets this number or zero crossing count as the indicator for the track for that segment 56. In practice, a zero crossing point can be detected whenever two successive digital samples have different signs, one positive and one negative, and the zero crossing count constitutes the number of times that such a point is detected during one segment 56. Figure 5 shows the successive zero crossing counts for each segment 56 for the master file as:

8, 6, 7, 5, 6, 8, 6, 6.

This series of numbers constitutes the master profile for the master file.

Likewise, Figure 5 shows a test profile for the first test file of:

6, 8, 4, 5, 7, 4, 2, 3.

The test profile for the second test file calculated in the same way is:

8, 6, 7, 5, 6, 8, 6, 6.

In order to compare a test file with the master file, the computer begins forming the test profile segment by segment, i.e. it forms the test profile dynamically, and it then begins comparing the test profile with the master profile segment by segment, i.e. again dynamically.

As indicated in Figure 5, the test indicators for the first test file shown in line (b) match the reference indicators for the master file only in the fourth segment 58. In practice, the computer would have already discarded the first test file as a non-match on the basis of a comparison of the first few segments 56. Turning to the second test file represented in line (c), it will be seen that the test indicators match the reference indicators for every segment. In practice, the computer does not form profiles that represent the entire content of the master file and test audio files, but only profiles that represent "clips" from the start of these files of some 15 seconds duration. It will the conclude that there is a match if these two profiles correspond.

It will be appreciated that a particular test file might appear to be a non-match with the master file simply because the tracks on which the files are based are not synchronised in time so that the first segment 56 of the master file starts at a different point of the analogue waveform than the first segment 56 of the test file. In order to deal with this situation, the computer is arranged to generate a number of different test profiles for one test file by discarding initial portions of the test signal at the start of the test track, as shown in Figure 6.

Figure 6 shows in line (a) the same master file as before, having the test code: 8, 6, 7, 5, 6, 8, 6, 6. Lines (b), (c) and (d) in Figure 6 represent a single test file from which first, second and third test profiles have been successively generated. The manner in which these subsequent test profiles are generated is illustrated in Figure 7.

Referring to Figure 7, a single segment 56 of the test file is shown enlarged, together with an incremental interval 60 designated delta-s1 immediately following the start of the segment and an incremental interval 62 designated delta-s2 immediately following the end of the segment. Delta-s1 represents the number of digital sampling intervals occurring between the starting point 64 of the segment 56 and the first zero crossing point 66 within the segment 56. Likewise, delta-s2 represents the number of digital sampling intervals between the ending point 68 of the segment 56 and the first zero crossing point 70 within the next segment. As will be appreciated, in order to change the zero crossing count for the particular segment illustrated, the starting point 64 of the segment must be shifted or delayed by an amount corresponding to delta-s1 or delta-s2, whichever is the smaller. In the example illustrated, delta-s1 is the smaller. Thus, the minimum shift needed to change the zero count of the segment 56 illustrated, and indeed of any one of the segments 56, is the smaller of delta-s1 and delta-s2 for that particular segment. If we call this value delta-seg, it follows that the minimum shift to generate a new test profile for the test file is a value which is the minimum delta-seg for all the segments, namely delta-min. Delta-min may in practice be a shift as small as 1/50000 second or less.

Returning now to Figure 6, the computer receiving the test signal shown in line (b) for checking, first forms a test profile 72 based on a segment starting point at the beginning of the test signal, which yields the test profile:

12, 7, 7, 4, 6, 8, 6, 8.

As is clear, this test profile does not correspond with the master profile for the master file. Consequently, the computer forms a second test profile 74 by establishing delta-s1 and delta-s2 for each segment and computing delta-seg from these two values. After scanning delta-seg for each of the segments and determining delta-min, the computer performs a shift on the test signal by an amount corresponding to delta-min and generates a new test profile 74 as shown in line (c) of Figure 6. This new test profile 74 is:

11, 7, 7, 5, 6, 8, 5, 7.

Again, it is apparent that this second test profile does not match the master profile for the master file.

Consequently, the computer generates a further test profile 76 in the same manner by determining delta-min based on the test signal as shifted once more. This produces a third test profile 76, which is:

8, 6, 7, 5, 6, 8, 6, 6.

As can be seen, the third test profile 76 does match the master profile for the master file and hence the computer generates an output indicating that the test file corresponds to the master file and hence that the audio track from which the test file has been generated corresponds to the master track from which the master file has been generated.

These steps are described more fully with reference to the flowcharts shown in Figure 8-12 below.

Referring to Figure 8, this shows a flowchart representing the generation of the master profile from the master file as indicated in step 14 shown in Figure 1. In step 100, the computer initiates this process. The computer reads the first segment of the master file in step 102 and determines the zero crossing count in step 104. In step 106, the computer adds the count established in step 104 to the profile formed so far. Next, the computer checks in step 108 whether the number of segments already read corresponds to the total number of segments required for the master profile. If the answer is no, the computer reverts to step 102 and reads the next segment. If the answer is yes, the computer proceeds to step 110 and stores the entire master profile in the database.

Figure 9 shows a flowchart representing the sub routine involved in step 104, as follows: The sub routine starts in step 112 and proceeds to step 114 where the computer initialises to zero a counter for detecting the zero crossing count. The computer then examines the digital number generated in the immediately following sampling interval in step 116, and in step 118 checks whether the sign has changed between positive and negative since the last sampling interval. If the answer is yes, the counter is incremented by 1 in step 120. On the other hand, if the answer is no, the computer proceeds to step 122 and checks whether the numbers from all the sampling intervals in the segment have yet been examined. If the outcome of step 122 is yes, the sub routine ends at step 124. On the other hand, if the outcome of step 122 is no, the computer returns to step 116 and examines the number from the next sampling interval.

The flowcharts illustrated in Figures 8 and 9 represent the production of the master profile as described above with reference to Figures 4 and 5.

Turning now to Figure 10, the step of selecting a test file and generating a test profile for comparison with the master profile will now be described. The computer starts the procedure at step 130, and in step 132 reads an initial clip or signal sequence from the test file. In step 134, the computer initialises to zero a counter for detecting a current displacement for the starting point of the first segment. The computer then proceeds to calculate the test profile and the value delta-s for each segment in the clip, as shown in step 136.

The sub routines included in step 136 are shown in Figure 11 and will now be described. The sub routine starts in step 138, and the computer proceeds in step 140 to set the start point for the segments to match the current displacement value, presently at zero. The computer continues to step 142 and determines the zero crossing count for the initial segment and delta-s for that segment. In step 144, the computer adds the zero crossing count determined in step 142 to a test profile store and in step 146 the computer adds delta-s calculated in step 142 to a store for all the values of delta-s. The computer proceeds to step 148 and checks whether the full test profile has yet been established. If the answer is yes, the computer proceeds to step 150 and the end of the sub routine. On the other hand, if the answer is no, the computer proceeds to step 152 and to the next segment by incrementing the current segment start point by an amount corresponding to the segment length. The computer then returns to step 142 to determine the zero crossing count and the delta-s for this new segment for storage in the test profile store and the delta-s store.

Turning to Figure 12, the sub routine involved in step 142 is illustrated and starts at step 154. In step 156, the computer initialises a counter for the zero

crossing count to zero, and in step 156 the computer examines the number from the next sampling interval. In step 158, the computer establishes whether the sign has changed since the last sampling interval. If the answer is no, the computer proceeds to step 160 and checks whether all the sampling intervals in the segment have yet been examined. If the answer is yes, the computer proceeds to step 162 and enquires whether the zero crossing count is currently zero. If the outcome of step 162 is yes, the computer sets delta-s to be equal to the current sample position within the segment as shown in step 164. If the outcome of step 162 is no, the computer proceeds to step 166 and increments the counter for the zero crossing count by 1. The computer then proceeds to step 160 and checks whether all the sampling intervals in the segment have yet been examined. If the outcome of step 160 is no, the computer returns to step 156 and examines the number from the next sampling interval. On the other hand, if the outcome of step 160 is yes, the computer proceeds to step 168 and again checks whether the zero crossing count is currently at zero. If the outcome of step 168 is no, the computer proceeds to the end of the sub routine in step 170. On the other hand, if the outcome of step 168 is yes, the computer proceeds to step 172 and sets delta-s to be equal to the length of the segment plus 1. This would signify that there had been no zero crossings within the segment and so delta-s is set to a distinguished value. The computer then proceeds to step 170 and follows on to step 144 in the sub routine shown in Figure 11.

Returning now to Figure 10, having calculated the test profile and the full list of delta-s values for the clip taken from the test file, the computer proceeds to step 174 and compares the test profile established thus far with the master profile for the master file. This corresponds with the steps illustrated in Figures 5 and 6.

In step 176, the computer enquires whether the profiles match and if the answer is yes the computer indicates in step 178 that a match has been found. The computer then proceeds to step 44 as shown in Figure 3.

On the other hand, if the outcome of step 176 indicates that the test profile does not match the master profile, the computer proceeds to step 180 and calculates the shift required in the starting point for the segments in order to generate a new test profile for the clip. As described above, with reference to Figure 7, the amount of the shift corresponds to the minimum value for delta-s generated for all the segments tested. This value delta-min is selected and the current displacement for the starting point of the initial segment is incremented by such an amount in step 182. The computer proceeds to step 184 and determines whether such an increment would result in there being insufficient remaining of the clip read in step 132 for a complete test profile to be formed. In step 186, the computer enquires whether the clip is exhausted and if the answer is no, the computer reverts to step 136 and continues to calculate the test profile and delta-s list starting from a shifted location for the initial segment. On the other hand, if the outcome of step 186 is that the clip has been exhausted, the computer concludes in step 188 that there is no match between the clip and the master file and proceeds to step 42 in Figure 3.

For the sake of simplicity, the description thus far is based on a number of assumptions, one of which is that the zero crossing count of a segment in the test profile must be precisely the same as the zero crossing count of the corresponding segment in the master profile for the two segments to be regarded as matching. In practice, however, this requirement is too rigid. It

does not cater for minor differences between the master and test files caused, for example, by the use of different audio encoding formats or by noise.

The required tolerance of such minor differences is achieved by relaxing the requirement for zero crossing counts to be identical. Instead, corresponding segments are regarded as matching if their zero crossing counts are very similar. Segment matching is then determined on the basis of the following equation:

$$[(ZX_{RMF}/margin\_p) - margin\_b] < ZX_{FFC} < [(ZX_{RMF} \times margin\_p) + margin\_b]$$

where:

ZX_{RMF} is the zero crossing count of the segment in the master file RMF

ZX_{FFC} is the zero crossing count of the segment in the test file FFC

margin_p is a *relative* margin for error

margin_b is an *absolute* margin for error

In practice, values for margin_p and margin_b of 1.1 and 10, respectively, work well. This allows a margin of ± (10%+10).

Another assumption made thus far is that the test track from which the test profile is derived starts a little before the master track from which the master profile is derived. In practice this may not be the case. There may be several seconds difference between the start of the two tracks, in either direction. The test track may have spurious material at the beginning or, conversely, an initial fragment of the master track may be missing.

The situation where the test track includes spurious material at the start is already covered by the algorithm described above. The algorithm simply keeps shifting through the test file, discarding the spurious material, until the test and master files are synchronised.

However, the situation wherein an initial fragment of the master track is missing from the test track requires a minor extension to the algorithm. This entails extending the master profile generation process shown in Figure 8 to produce not just a single master profile for the given master file, but rather a set of such master profiles. Each such profile captures a 15 second clip from the master file. The first starts at the very beginning of the master file. The next begins 1.5 seconds into the master file. The next begins 3 seconds in, and so on, in 1.5 second increments, up to a maximum of 15 seconds. This gives a total of 11 master profiles for a single master file. All these 11 profiles can be formed by generating a single long profile capturing the first 30 seconds of the master file, as shown in Figure 8, and dynamically extracting the appropriate sub-sequences from that long profile as it is being formed.

The files comparison process then remains as shown in Figure 10, but with just one modification. Instead of comparing the test profile with just a single master profile, the comparison is made with all 11 profiles – the "base" profile and all the "late start" profiles.

This arrangement caters for missing fragments of any length up to 15 seconds. Any fine synchronisation necessitated by the missing fragment not being an exact multiple of 1.5 seconds is provided by the normal shifting mechanism. So with this extension, the algorithm is able to find a match when any 15 second sequence from the first 30 seconds of the test file matches any fifteen second sequence from the first 30 seconds of the master file.

Turning now to Figures 13-16, a modification of the basic shifting segment algorithm will now be described. This modification is intended to optimise the performance of the present invention in two ways as follows:

(1) By calculating the zero crossing count for each respective segment of the test file successively and concurrently comparing that count with the corresponding count shown in the master profile.

(2) By avoiding recalculation of the zero crossing count for the previously considered segments wherever possible.

Thus, the process discontinues the computation of the test profile at a given shift position as soon as the first non-matching segment is found, but wherever possible re-uses previously computed values when forming the profile at the next shift position. Each test file is thereby dynamically compared with the master file.

This process is represented in the flowchart of Figure 13 in which step 200 represents the selection of a particular test file containing a particular test track. In step 202, the computer sets a counter for counting the number of segments considered in the test track to zero, and in step 204 the computer initialises the first segment by setting the starting and ending points of the segment and by calculating the segments zero crossing count, together with delta-s 1, delta-s 2 and delta-seg. The computer proceeds to step 206 where it makes a comparison of the zero crossing count for the first segment of the test file and the zero crossing count for the first segment of the master file. If there is a match, the computer proceeds to step 208 and enquires whether enough segments match to indicate that the test file corresponds with the master file. Since this is the first segment, the answer will be no and so the computer proceeds to step 210 where

it increments the segment counter by 1 and moves onto the next segment. In step 212, the computer initialises the next segment using the sub routine shown in Figure 14, and then it reverts to step 206 to check once more whether this a match between the next segment of the test file and the corresponding segment of the master file.

If no match is found at step 206, the computer proceeds to step 214 and checks whether the starting point of the current segment can be shifted without undoing matches already established for the preceding segments. This process is described below with reference to Figure 15. The outcome of such a check is established in step 216 and, if the shift is found to be possible, the computer proceeds to make such a shift in step 218 and then reverts to step 206 to check once again whether there is a match between the current segment of the test file and the corresponding segment of the master file. On the other hand, if the outcome of step 216 is an indication that a shift cannot be made without undoing matches established for the preceding segments, the computer proceeds to step 220. In step 220, the computer enquires whether the counter showing the number of the current segment is at zero. If the answer is yes, the computer assumes that no match is possible between the test file and the master file and proceeds to the end of the optimised procedure in step 222. However, if the counter is not at zero, the computer proceeds to step 224 and decrements the counter by 1 thereby reverting to the immediately preceding segment for reconsideration. At this point, the computer returns to step 214 and checks whether a shift of this preceding segment is possible without undoing matches already established for the segments prior to that.

Figure 14 is a flowchart showing the sub routine comprising step 204. This sub routine begins in step 230 with an instruction to initialise the segment currently being considered. In step 232, the computer sets the start point for the current segment to correspond with the end point of the previous segment plus one sampling interval. The computer proceeds to step 234 where it sets the end point for the current segment to correspond to the start point for the current segment plus the segment length. After this, in step 236, the computer calculates for the segment: the zero crossing count, the value delta-s 1 corresponding to the distance from the segment starting point to the first zero crossing point as shown in Figure 7, the value delta-s 2 corresponding to the distance from the segment end point to the first subsequent zero crossing as shown in Figure 7, and the value delta-seg which is the lesser of delta-s 1 and delta-s 2. The computer proceeds then to step 236 and sets a value for the segment known as delta-running. Delta-running corresponds to the maximum distance that a later segment can be shifted without altering the zero crossing count of the present or any earlier segments. Initially, this value is calculated to be the lesser of the values delta-seg for the present segment and delta-running for the previous segment. Finally, the computer proceeds to step 240 and sets a value known as delta-used for the present segment to zero. Delta-used represents the total amount by which a particular segment has already been shifted from its original starting point. This brings the computer to the end 242 for the sub routine for initialising a particular segment.

Figure 15 shows a flowchart for the sub routine involved in step 214 for testing whether the segment currently being considered can be shifted or not. This sub routine commences at step 250, following which the computer proceeds to step 252. In step 252, the computer enquires whether the sum delta-seg plus delta-

used for the current segment exceeds the value delta-running for the previous segment. If the answer is yes, the computer proceeds to step 254 and determines that a shift is not possible. If the answer is no, the computer proceeds to step 256 and determines that a shift is possible.

Turning finally to Figure 16, the sub routine involved in step 218 for shifting the current segment will now be described. This sub routine commences at step 260 as shown. The computer proceeds to step 262 and adds the value delta-seg to the value delta-used for the segment signifying that the segment is being shifted by delta-seg relative to whatever shifts have already occurred amounting to the value delta-used. This is implemented in step 264 where the value delta-seg is added to the start point and the end point for the segment. Next, in step 266, the computer subtracts the value delta-seg from the previous delta-s 1 for the segment. In step 268, the computer checks whether the new delta-s 1 is now equal to zero. If the answer is yes, this means that a zero crossing has been removed from the front of the segment by the shift, and the computer decrements the value in the counter for the zero crossing count by 1 in step 270. The computer then proceeds in step 272 to calculate a new delta-s 1 for the segment. Subsequently, either because the outcome of step 268 is an no or following the calculation of step 272, the computer proceeds to step 274 and subtracts from the value delta-s 2 for the segment the value delta-seg. In step 276, the computer then checks whether the value delta-s 2 is now zero or not. If the answer is yes, this indicates that a new zero crossing has been added at the end of the segment and the computer increments the counter for the zero crossing count for the segment by 1 in step 278. Subsequently, the computer calculates a new value delta-s 2 for the segment in step 280. After this, either because the outcome of step 276 is a no or having calculated a new delta-s 2 in

step 280, the computer proceeds to step 282. In step 282, the computer sets a new value for delta-seg as the lesser of the present values for delta-s 1 and delta-s 2. Having made a shift, delta-running for the segment must also be recalculated and this is effected in step 284. In this step, the new delta-running is set to be the lesser of (i) the value delta-running for the previous segment minus the value delta-used for the current segment and (ii) the value delta-seg for the current segment. The sub routine for shifting the current segment is thus completed.

By means of the optimisation procedure described with reference to Figures 13-16, a very significant enhancement of the basic file matching algorithm is possible. Significantly, the speed of identification is greatly increased and therefore the number of unknown files which can be checked is also greatly increased.

The present invention has a number of significant benefits by comparison with known arrangements for comparing audio tracks or files.

Most significantly, it is unnecessary for two files being compared to be identical in their digital encodement for a match to be found. They can differ in various ways while still containing the "same" audio track. For example, the test track may have an initial fragment missing or it may contain additional material at the beginning. Equally, waveform variations caused by different digital coding formats, noise spikes or background noise, for example, can be accommodated.

These tolerances enable the invention to have a range of important applications, including the identification of illegal copies of a given audio track made

available, for example, on the Internet. Copies that have been captured in a variety of different ways, for example through the use of different MP3 conversion programs, through bootleg recordings of live concerts, or through radio or television broadcasts, can be detected and matched, which would hitherto have been impossible.

Other benefits of the present invention include its speed, so that it is practical to compare a single unknown test file with many hundreds of master files stored in the database or to monitor an audio source such as a radio broadcast or webcast to identify any correspondences with the master files currently held in the database.

In addition, the invention is suited to standard industry hardware. Furthermore, there is no need to employ a watermark or in other ways to modify the original master track for correspondences to be found.

CLAIMS

1. A method for identifying electronic files under test, the method comprising the steps of:

reading a master file including a master signal sequence,

dividing the master signal sequence into segments,

generating a reference indicator representing each master signal segment,

storing the respective reference indicators as a master profile,

reading a test file including a test signal sequence,

dividing the test signal sequence into segments,

generating respective test indicators for successive segments of the test signal sequence to form a test profile,

comparing the reference indicators and the test indicators successively for respective corresponding segments of the master and the test signal sequences,

determining whether the reference indicators and the test indicators match, and

generating a corresponding indication.

2. A method according the claim 1 comprising generating a plurality of test profiles for a respective test file by:

creating a first set of segments commencing from a first predetermined point of the test signal sequence for generating a first test profile,

shifting the first predetermined point by a predetermined amount to a new predetermined point of the test signal sequence, and

creating a new set of segments commencing from the new predetermined point to form another test profile.

3. A method according to claim 1 or 2 comprising effecting a dynamic comparison of the reference indicators and the test indicators by:

performing the step of generating the respective test indicators and the step of comparing the reference and the test indicators for successive corresponding segments concurrently.

4. A method according to claim 2, or claim 3 when dependent from claim 2, comprising optimising the procedure for generating each new test profile by:

computing a shift relative to the first predetermined point on an ongoing basis on each occasion that comparison of a respective reference indicator and a corresponding test indicator produces a non-match, and

generating the respective new test profile.

5. A method according to claim 4 in which the computation comprises re-using previously generated test indicators forming an initial portion of a respective test profile in the event:

a) that such test indicators match the corresponding reference indicators, and

b) that a shift relative to the associated predetermined point for subsequently generated test indicators will not undo the match.

6. A method according to any preceding claim comprising generating a plurality of master profiles for a respective master file by:

creating a first set of segments commencing from a first predetermined point of the master signal sequence for generating a first master profile,

shifting the first predetermined point by a predetermined amount to a new predetermined point of the master signal sequence, and

creating a new set of segments commencing from the new predetermined point to form another master profile.

7. A method according to any preceding claim comprising generating each reference indicator and/or each test indicator by:

detecting the number of occasions that the associated signal sequence traverses a predetermined base reference in the corresponding segment.

8. A method according to any preceding claim in which the step of determining whether the reference and the test indicators match comprises determining whether there is identity between the reference and the test indicators within predetermined tolerances.

9. Apparatus for identifying electronic files under test, the apparatus comprising:

means for reading a master file including a master signal sequence,

means for dividing the master signal sequence into segments,

means for generating a reference indicator representing each master signal segment,

a store for storing the respective reference indicators as a master profile,

means for reading a test file including a test signal sequence,

means for dividing the test signal sequence into segments,

means for generating respective test indicators for successive segments of the test signal sequence to form a test profile,

means for comparing the reference and test indicators successively for respective corresponding segments of the master and the test signal sequences,

means for determining whether the reference and the test indicators match, and

means for outputting a corresponding indication.

10. Apparatus according to claim 9 comprising means for generating a plurality of test profiles relating to a respective test file including:

means for generating a set of segments commencing from a predetermined point of the test signal sequence for generating a respective test profile, and

means for shifting the predetermined point of the test signal sequence by a predetermined amount for generating another test profile.

11. Apparatus according to claim 9 or 10 comprising means for effecting a dynamic comparison of the reference indicators and the test indicators including:

control means arranged to operate the means for generating the respective test indicators and the comparing means concurrently.

12. Apparatus according to claim 10, or claim 11 when dependent from claim 10, comprising means for optimising the procedure for generating each test profile including:

means for computing a shift relative to a respective predetermined point in response to an indication from the outputting means that a respective reference indicator and a corresponding test indicator do not match.

13. Apparatus according to claim 12 in which the computation means comprises:

means for storing previously generated test indicators forming an initial portion of a respective test profile in the event that such test indicators match the corresponding reference indicators, and

means for checking whether a shift relative to the associated predetermined point for subsequently generated test indicators will undo the match.

14. Apparatus according to any of claims 9 to 13 comprising means for generating a plurality of master profiles relating to a respective master file including:

means for generating a set of segments commencing from a predetermined point of the master signal sequence for generating a respective master profile, and

means for shifting the predetermined point of the master signal sequence by a predetermined amount for generating another master profile.

15. Apparatus according to any of claims 9 to 14 in which the means for generating each reference indicator and/or each test indicator comprises:

means for detecting the number of occasions that the associated signal sequence traverses a predetermined base reference in the corresponding segment.

16. Apparatus according to any of claims 9 to 15 in which the means for determining whether the reference and the test indicators match are arranged to determine whether there is identity between the reference and the test indicators within predetermined tolerances.

Fig.1.

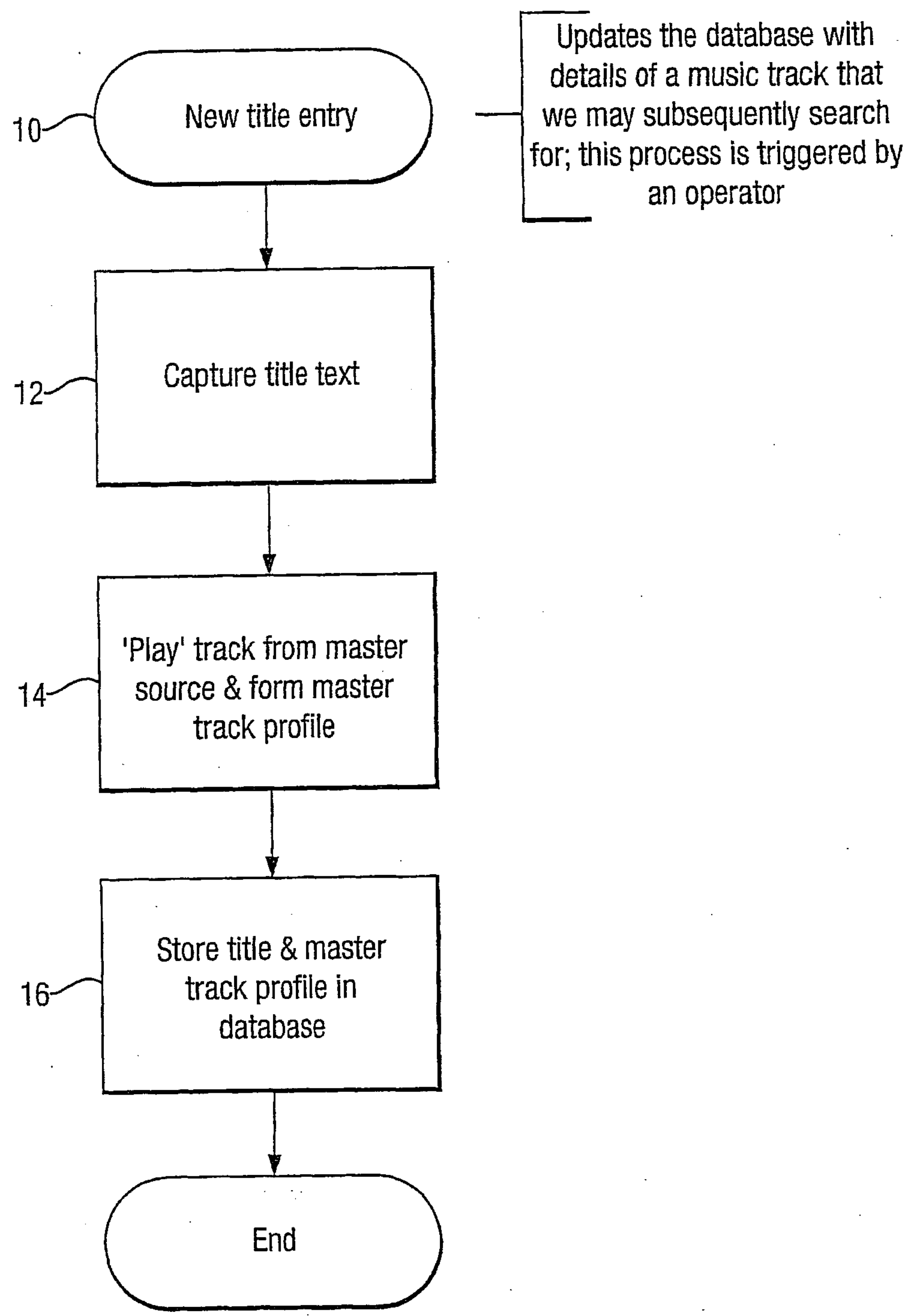

New title entry
Updates the database with details of a music track that we may subsequently search for; this process is triggered by an operator
Capture title text
'Play' track from master source & form master track profile
Store title & master track profile in database
End
10
12
14
16

Fig.2.

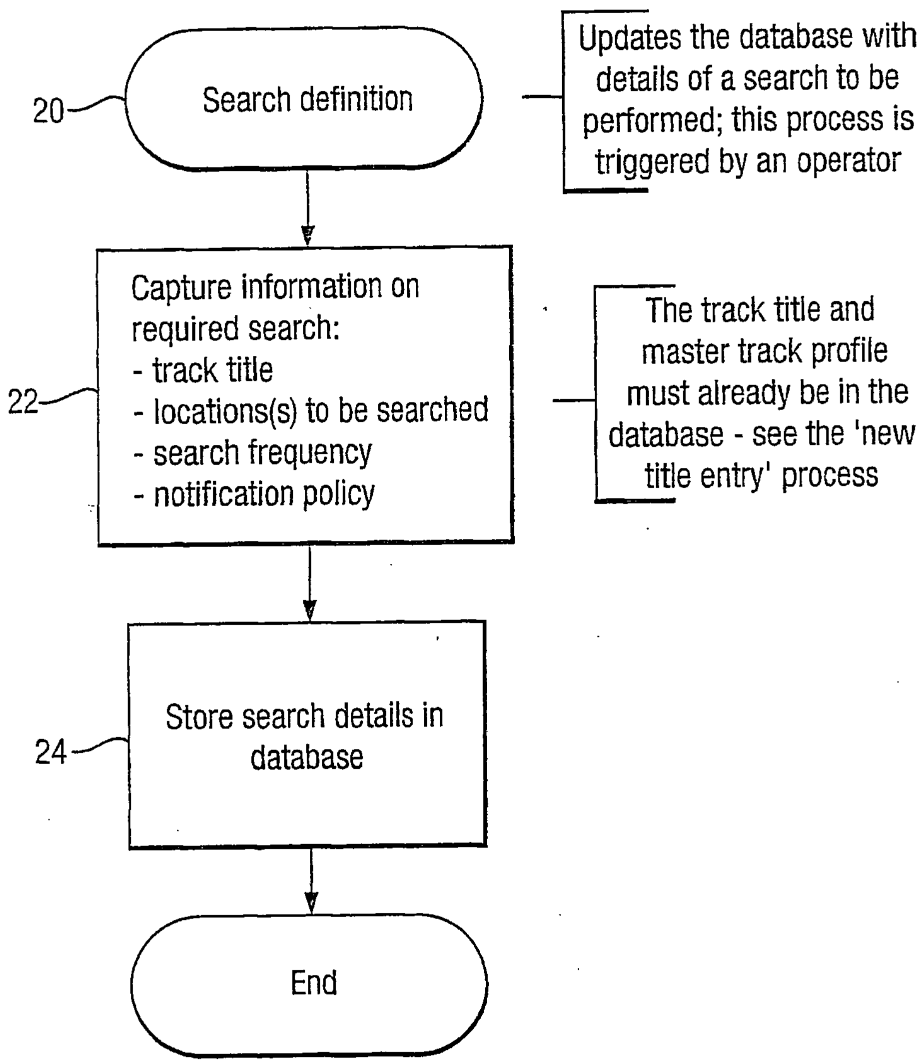
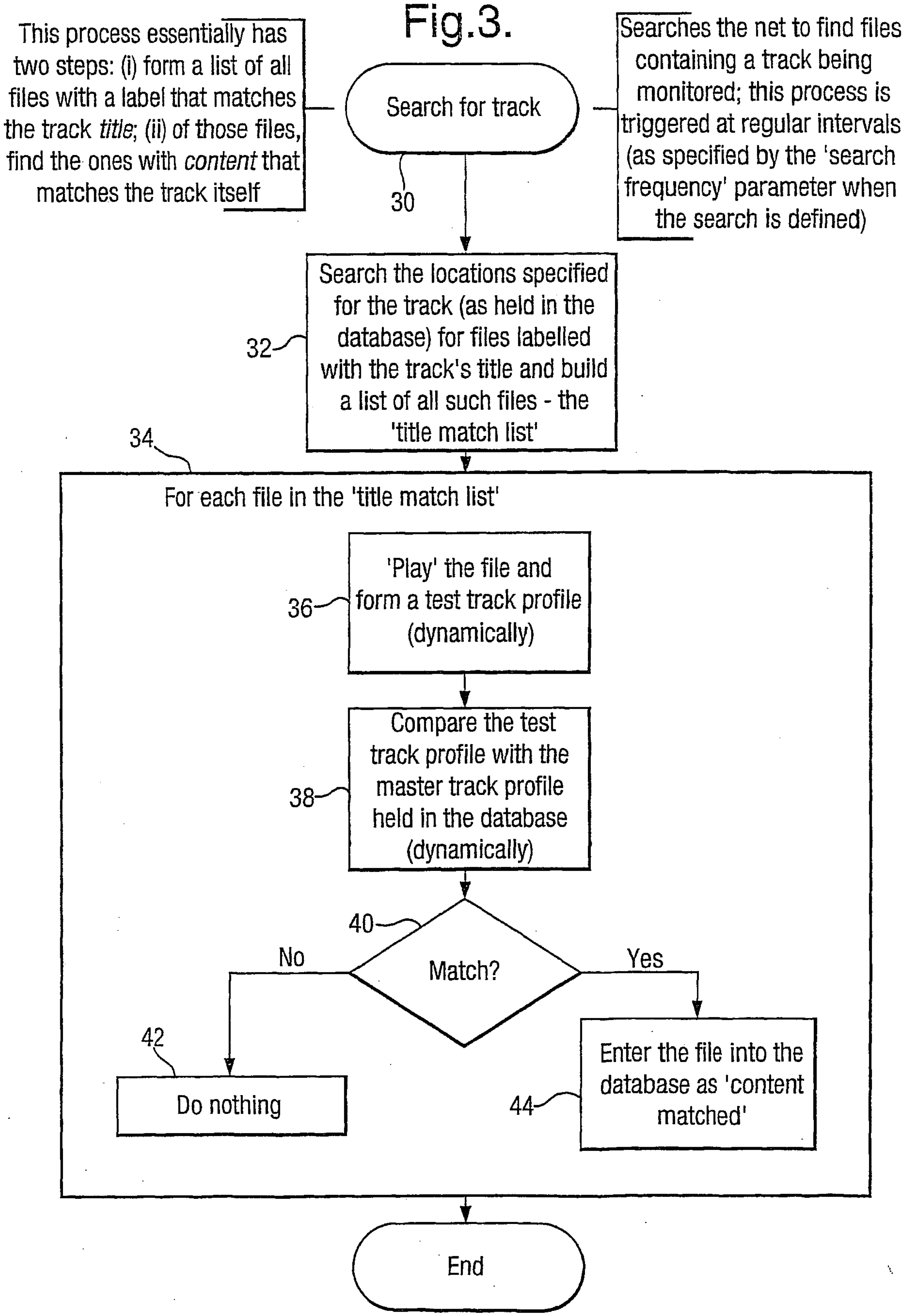

Search definition
20
Updates the database with details of a search to be performed; this process is triggered by an operator
Capture information on required search:
- track title
- locations(s) to be searched
- search frequency
- notification policy
22
The track title and master track profile must already be in the database - see the 'new title entry' process
Store search details in database
24
End

Fig.3.


This process essentially has two steps: (i) form a list of all files with a label that matches the track *title*; (ii) of those files, find the ones with *content* that matches the track itself
Search for track
Searches the net to find files containing a track being monitored; this process is triggered at regular intervals (as specified by the 'search frequency' parameter when the search is defined)
30
Search the locations specified for the track (as held in the database) for files labelled with the track's title and build a list of all such files - the 'title match list'
32
34
For each file in the 'title match list'
'Play' the file and form a test track profile (dynamically)
36
Compare the test track profile with the master track profile held in the database (dynamically)
38
40
Match?
No
Yes
42
Do nothing
Enter the file into the database as 'content matched'
44
End

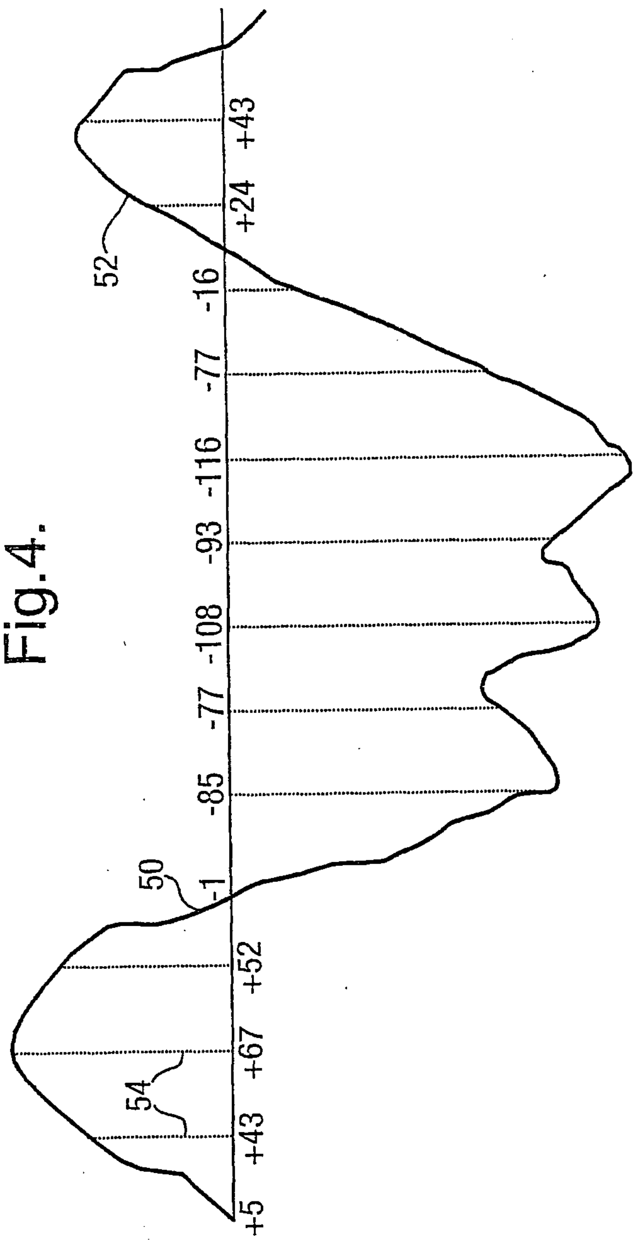


Fig.4.

Fig.5.

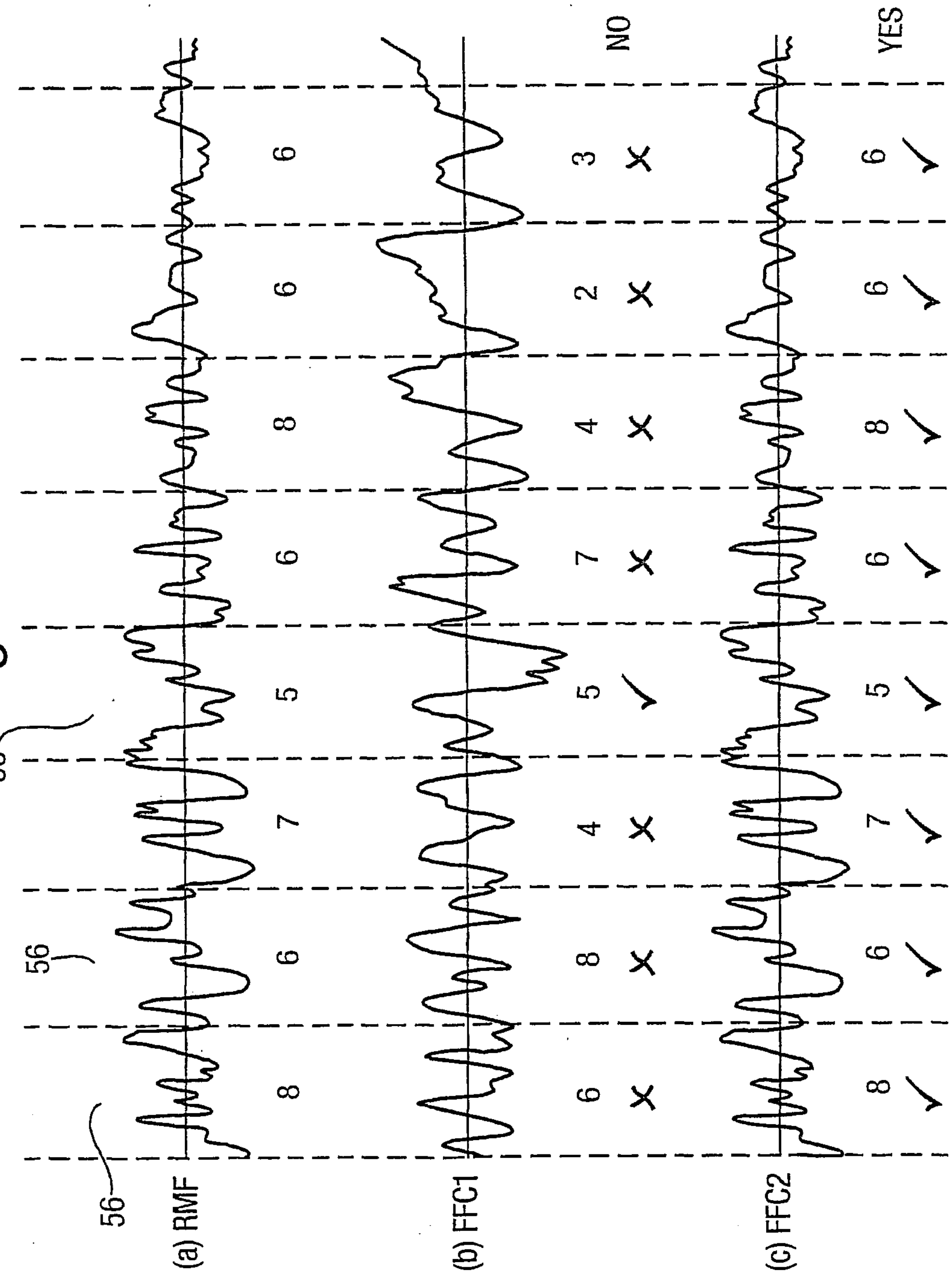


Fig.6.

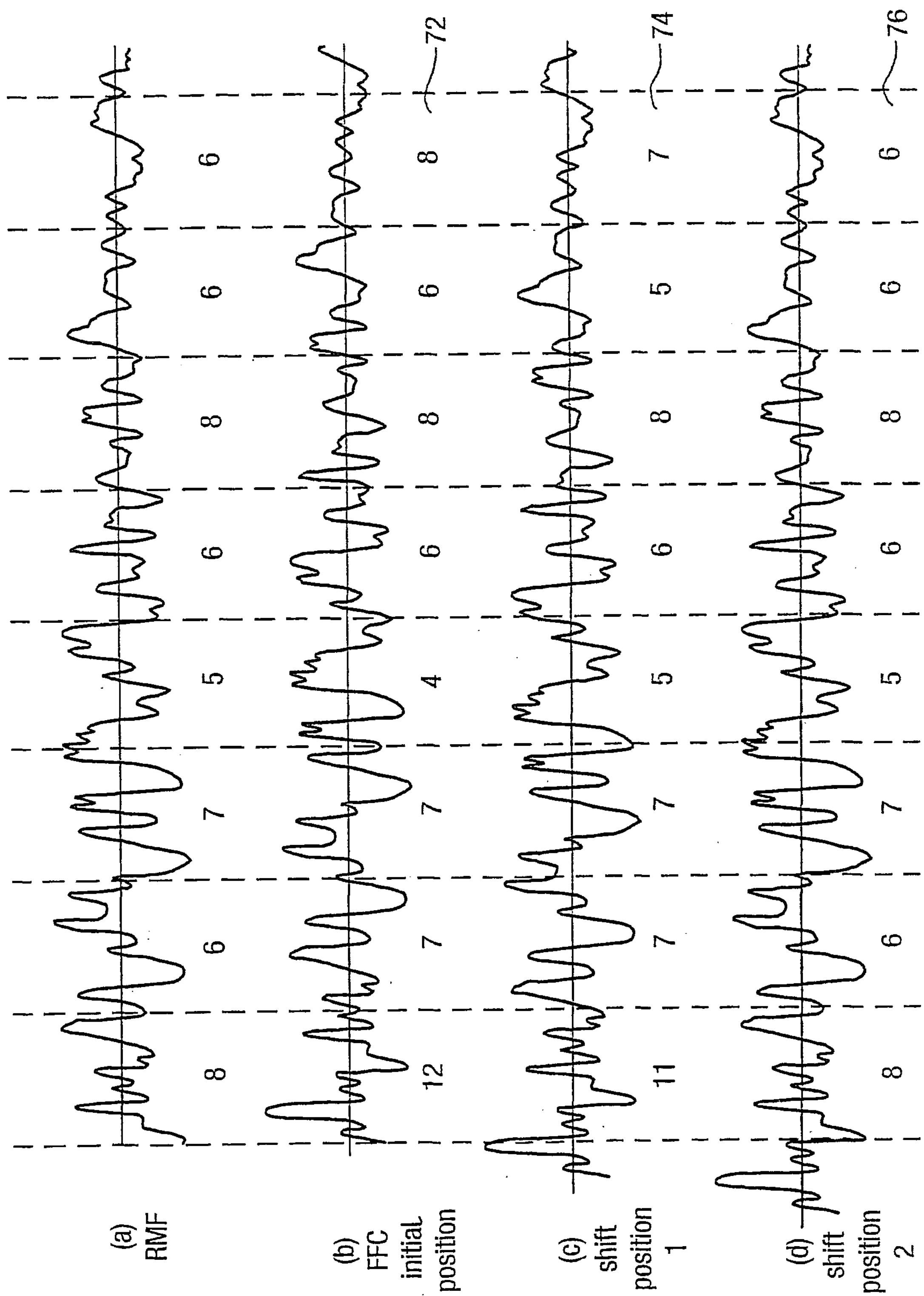

(a) RMF
(b) FFC initial position
(c) shift position 1
(d) shift position 2
8 6 7 5 6 8 6 6
12 7 7 4 6 8 6 8
11 7 7 5 6 8 5 7
8 6 7 5 6 8 6 6
72
74
76

Fig.7.

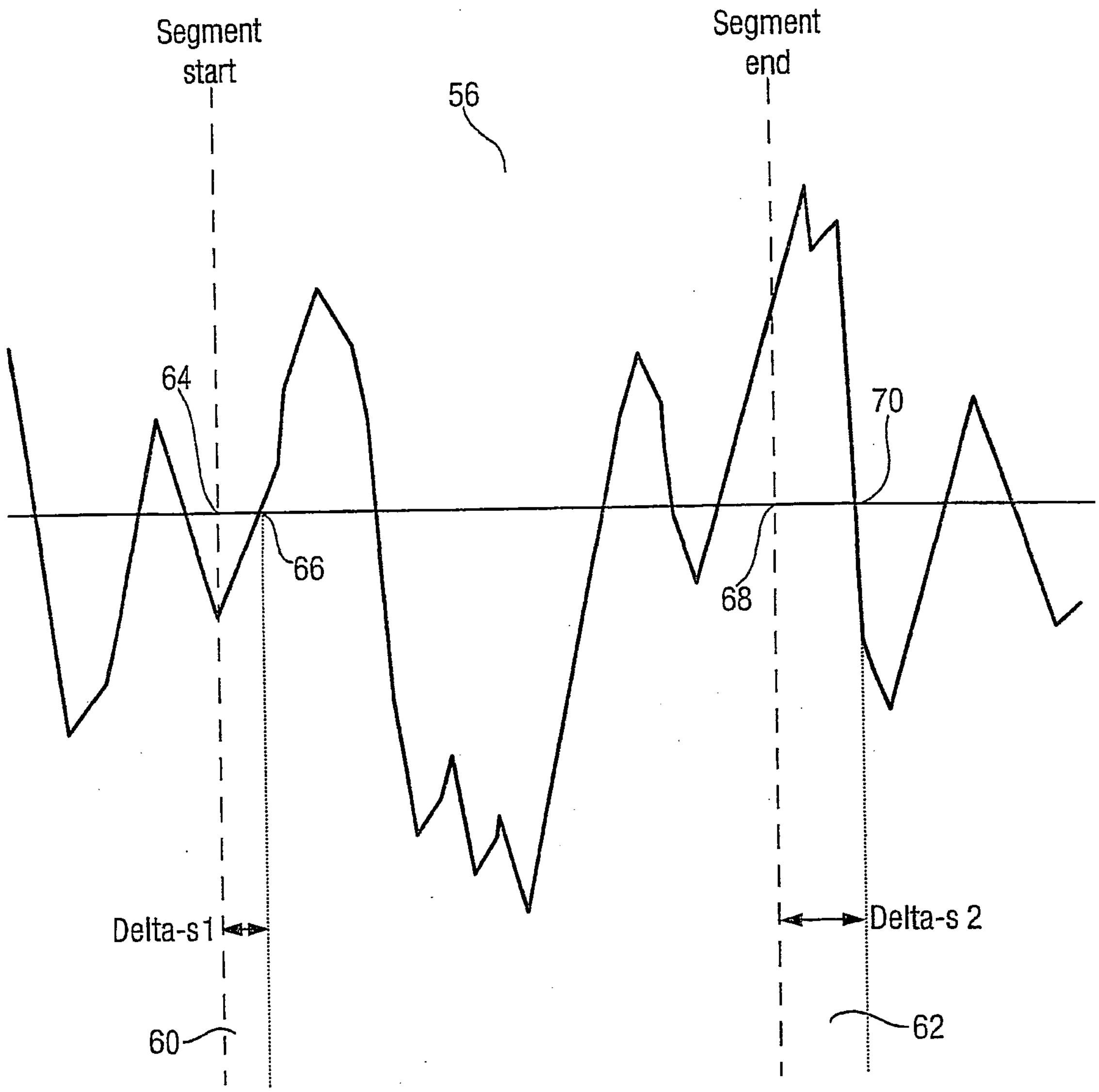

Segment start
Segment end
56
64
70
66
68
Delta-s1
Delta-s 2
60
62

Fig.8.

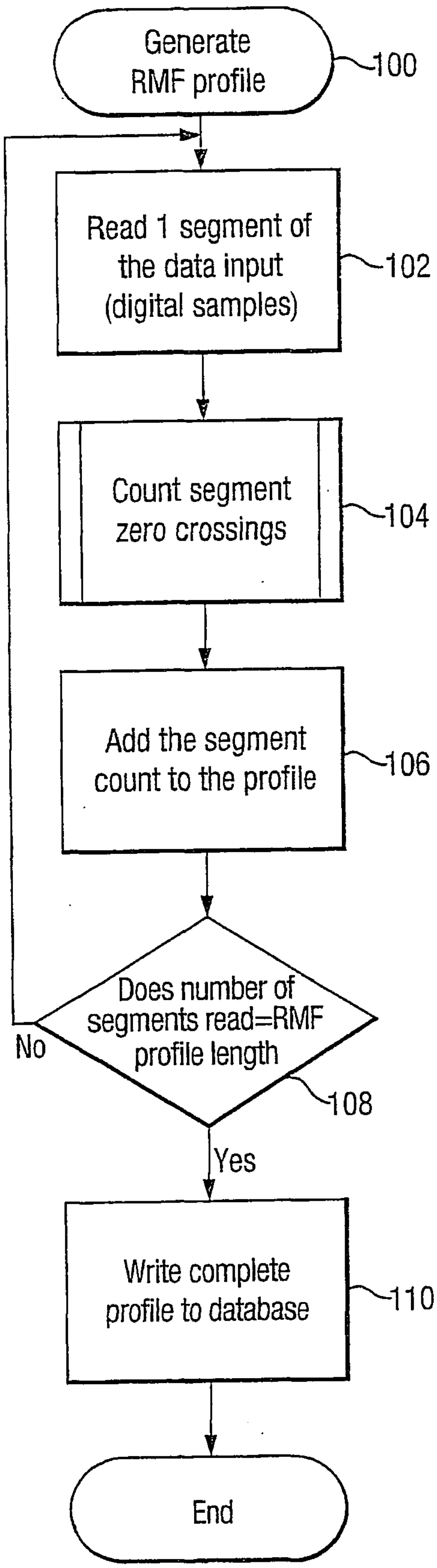

Generate RMF profile
100
Read 1 segment of the data input (digital samples)
102
Count segment zero crossings
104
Add the segment count to the profile
106
Does number of segments read=RMF profile length
No
108
Yes
Write complete profile to database
110
End

Fig.9.

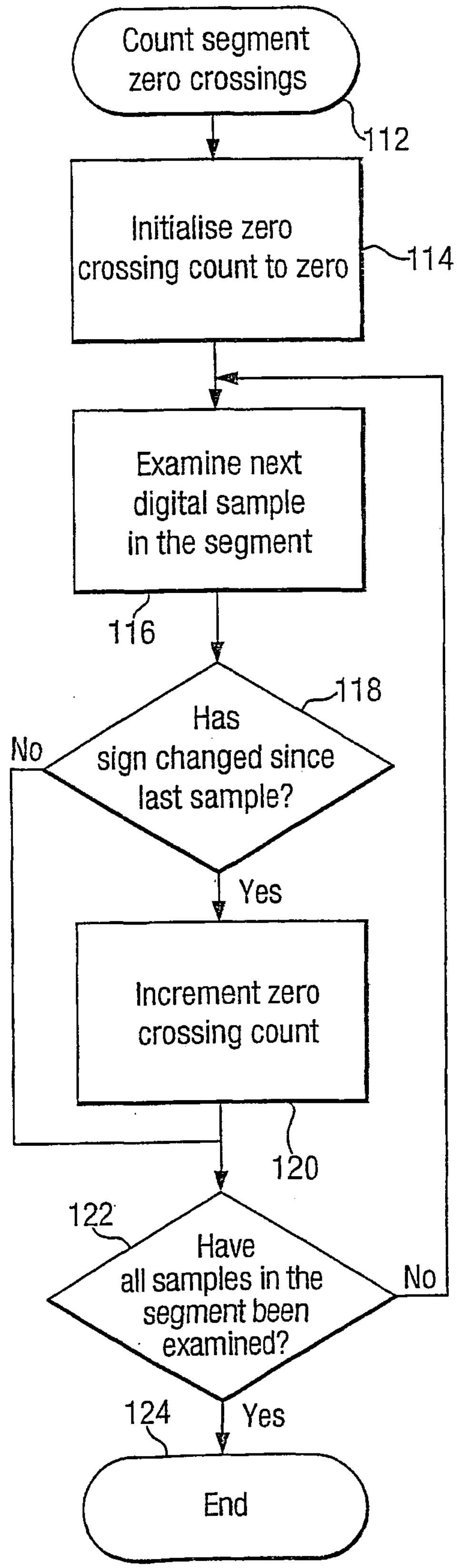

Count segment zero crossings
112
Initialise zero crossing count to zero
114
Examine next digital sample in the segment
116
Has sign changed since last sample?
118
No
Yes
Increment zero crossing count
120
122
Have all samples in the segment been examined?
No
124
Yes
End

Fig.10.

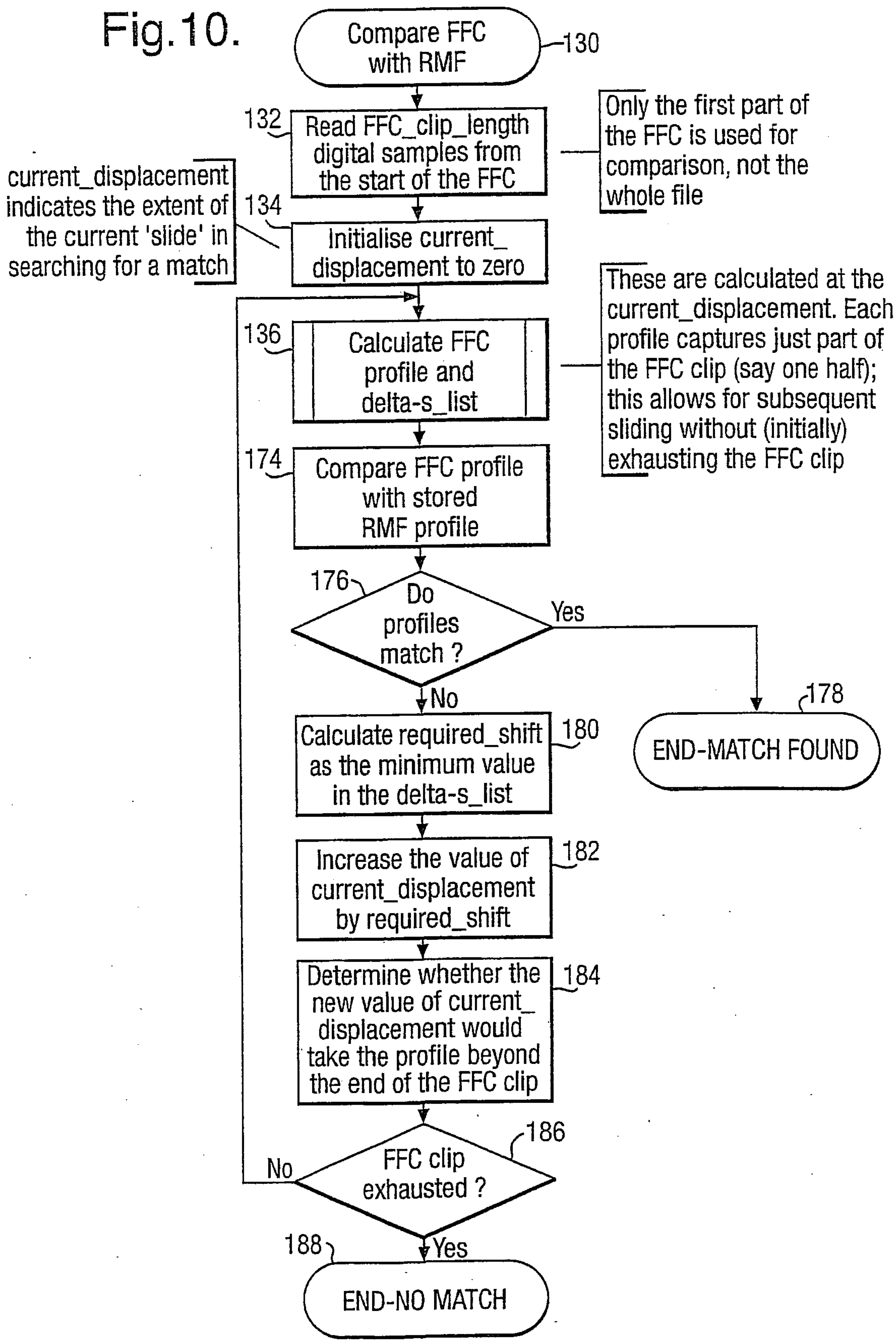

Compare FFC with RMF
130
132
Read FFC_clip_length digital samples from the start of the FFC
Only the first part of the FFC is used for comparison, not the whole file
current_displacement indicates the extent of the current 'slide' in searching for a match
134
Initialise current_displacement to zero
These are calculated at the current_displacement. Each profile captures just part of the FFC clip (say one half); this allows for subsequent sliding without (initially) exhausting the FFC clip
136
Calculate FFC profile and delta-s_list
174
Compare FFC profile with stored RMF profile
176
Do profiles match ?
Yes
178
END-MATCH FOUND
No
Calculate required_shift as the minimum value in the delta-s_list
180
Increase the value of current_displacement by required_shift
182
Determine whether the new value of current_displacement would take the profile beyond the end of the FFC clip
184
186
No
FFC clip exhausted ?
188
Yes
END-NO MATCH

Fig.11.

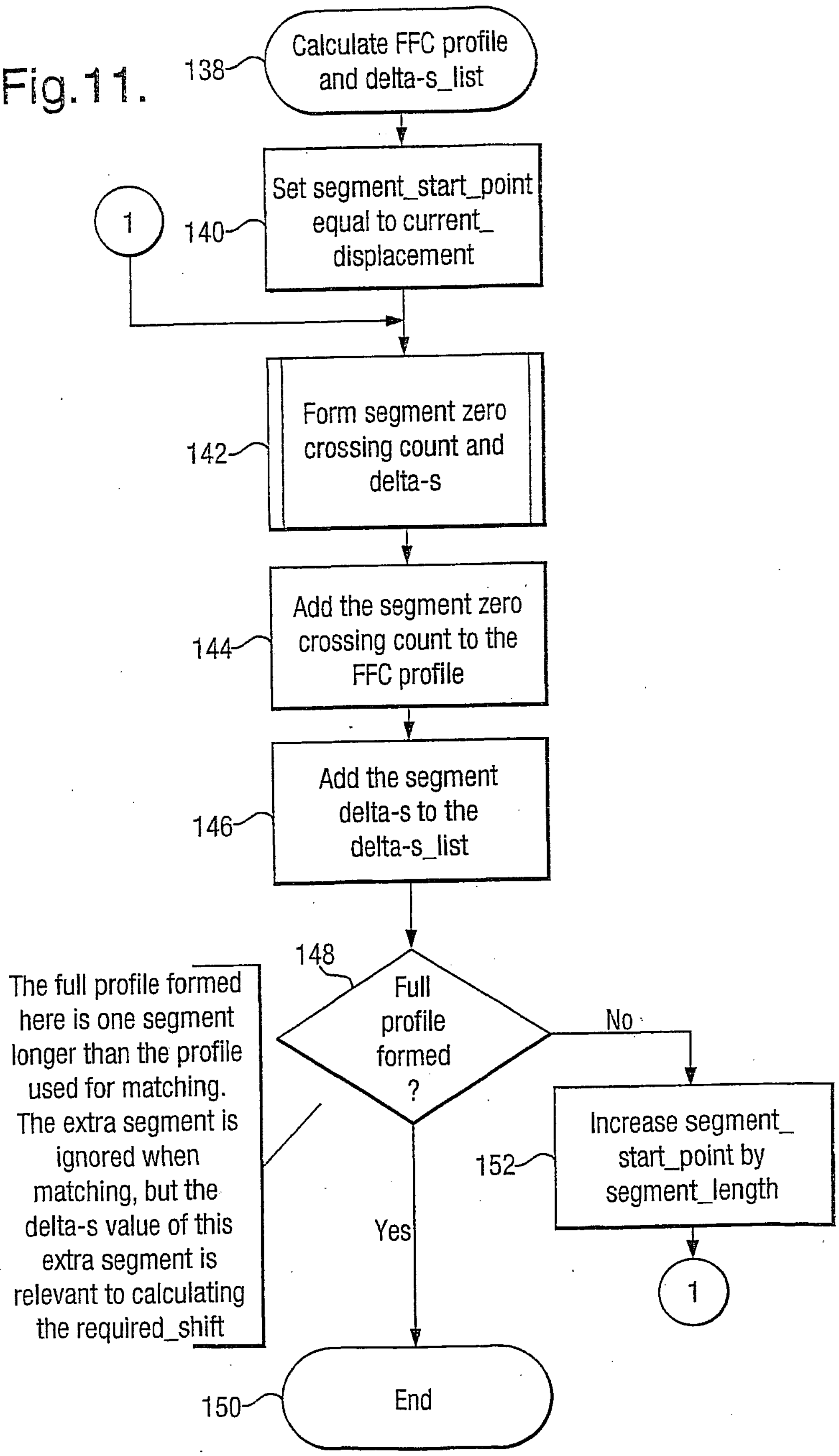

138
Calculate FFC profile and delta-s_list
140
Set segment_start_point equal to current_ displacement
1
142
Form segment zero crossing count and delta-s
144
Add the segment zero crossing count to the FFC profile
146
Add the segment delta-s to the delta-s_list
148
Full profile formed ?
No
152
Increase segment_ start_point by segment_length
1
Yes
The full profile formed here is one segment longer than the profile used for matching. The extra segment is ignored when matching, but the delta-s value of this extra segment is relevant to calculating the required_shift
150
End

Fig.12.

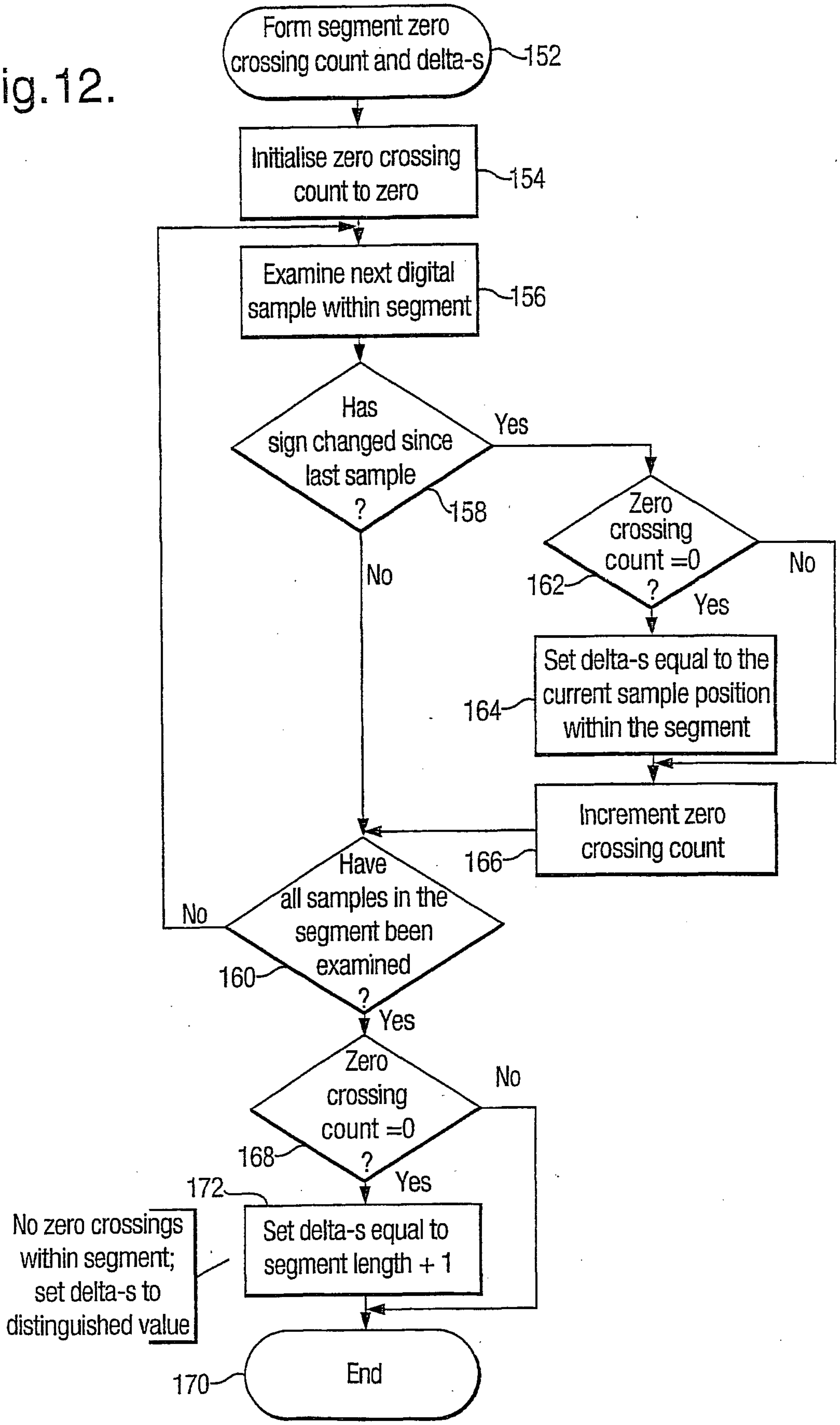

Form segment zero crossing count and delta-s
152
Initialise zero crossing count to zero
154
Examine next digital sample within segment
156
Has sign changed since last sample ?
158
Yes
No
Zero crossing count =0 ?
162
No
Yes
Set delta-s equal to the current sample position within the segment
164
Increment zero crossing count
166
Have all samples in the segment been examined ?
160
No
Yes
Zero crossing count =0 ?
168
No
Yes
172
Set delta-s equal to segment length + 1
No zero crossings within segment; set delta-s to distinguished value
End
170

Fig.13.

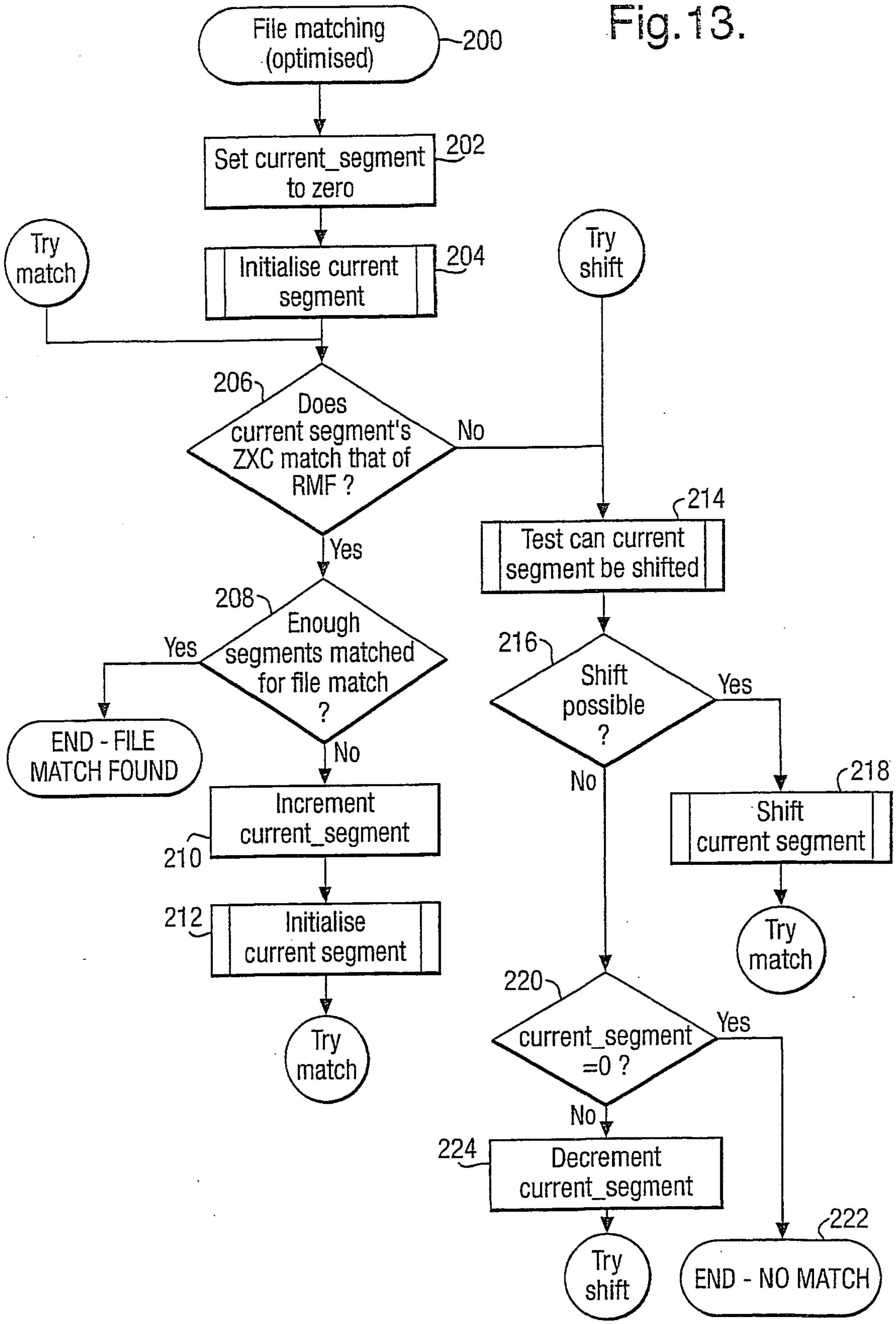

File matching (optimised)
200
Set current_segment to zero
202
Initialise current segment
204
Try match
Try shift
206
Does current segment's ZXC match that of RMF ?
No
Yes
214
Test can current segment be shifted
208
Enough segments matched for file match ?
Yes
No
END - FILE MATCH FOUND
216
Shift possible ?
Yes
No
218
Shift current segment
Increment current_segment
210
212
Initialise current segment
Try match
Try match
220
current_segment =0 ?
Yes
No
224
Decrement current_segment
Try shift
222
END - NO MATCH

Fig.14.

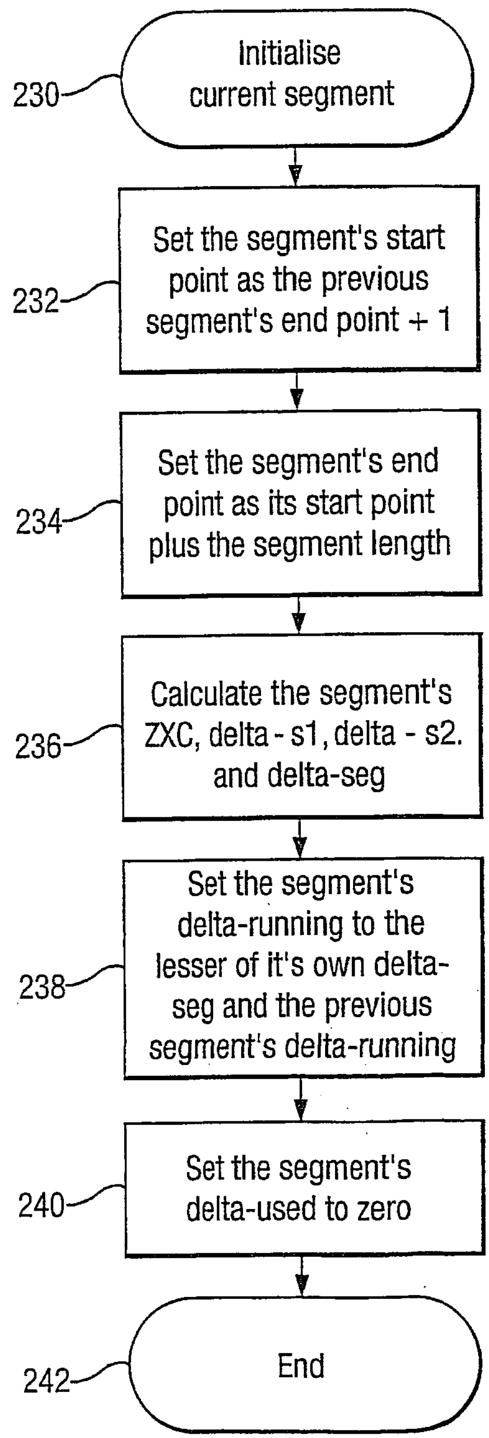

Initialise current segment
230
Set the segment's start point as the previous segment's end point + 1
232
Set the segment's end point as its start point plus the segment length
234
Calculate the segment's ZXC, delta - s1, delta - s2. and delta-seg
236
Set the segment's delta-running to the lesser of it's own delta-seg and the previous segment's delta-running
238
Set the segment's delta-used to zero
240
End
242

Fig.15.

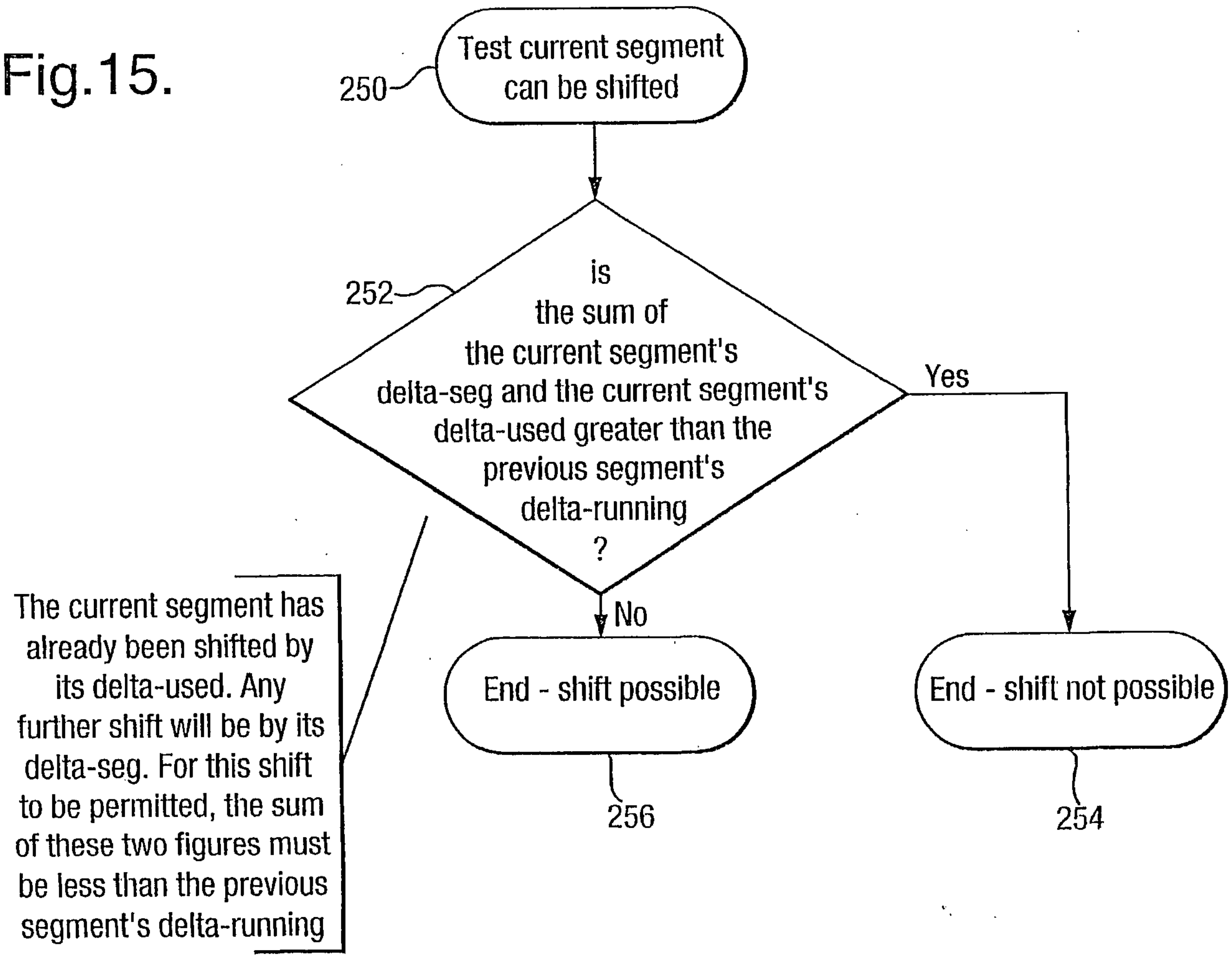
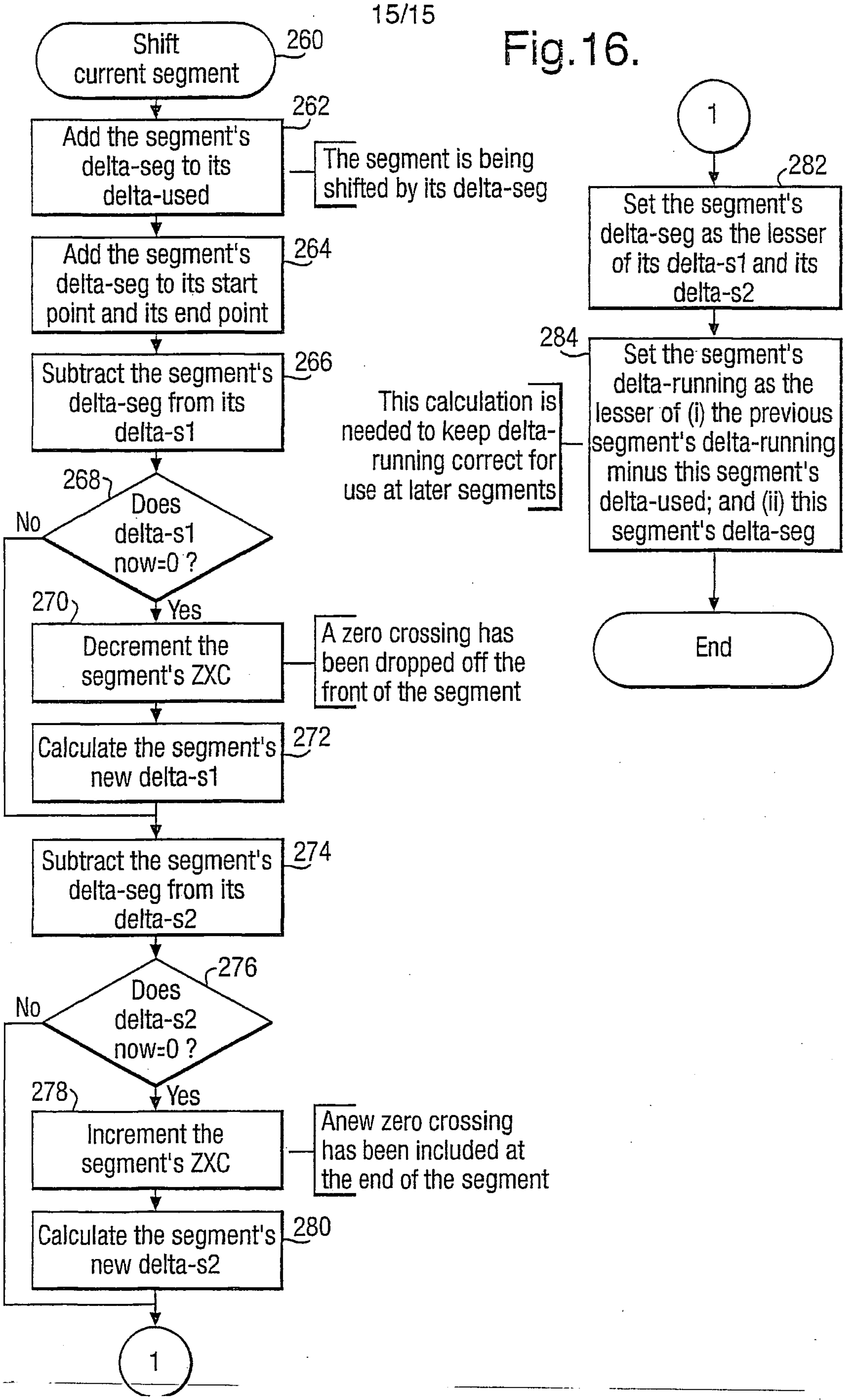

250
Test current segment can be shifted
252
is the sum of the current segment's delta-seg and the current segment's delta-used greater than the previous segment's delta-running ?
Yes
No
End - shift possible
256
End - shift not possible
254
The current segment has already been shifted by its delta-used. Any further shift will be by its delta-seg. For this shift to be permitted, the sum of these two figures must be less than the previous segment's delta-running

Fig.16.


Shift current segment
260
Add the segment's delta-seg to its delta-used
262
The segment is being shifted by its delta-seg
Add the segment's delta-seg to its start point and its end point
264
Subtract the segment's delta-seg from its delta-s1
266
268
Does delta-s1 now=0 ?
No
Yes
270
Decrement the segment's ZXC
A zero crossing has been dropped off the front of the segment
Calculate the segment's new delta-s1
272
Subtract the segment's delta-seg from its delta-s2
274
276
Does delta-s2 now=0 ?
No
Yes
278
Increment the segment's ZXC
Anew zero crossing has been included at the end of the segment
Calculate the segment's new delta-s2
280
1
1
282
Set the segment's delta-seg as the lesser of its delta-s1 and its delta-s2
284
Set the segment's delta-running as the lesser of (i) the previous segment's delta-running minus this segment's delta-used; and (ii) this segment's delta-seg
This calculation is needed to keep delta-running correct for use at later segments
End

INTERNATIONAL SEARCH REPORT

national Application No
PCT/GB 02/01347

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06F17/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01 11496 A (FINN BENJAMIN JAMES ;FINN JONATHAN HUMBERT (GB); SIBELIUS SOFTWARE) 15 February 2001 (2001-02-15) page 11, line 13 -page 12, line 9 page 13, line 10 -page 14, line 19 page 23, line 29 -page 24, line 27 ---	1,2,6, 8-10,14, 16
X	US 5 918 223 A (KEISLAR DOUGLAS F ET AL) 29 June 1999 (1999-06-29)	1,8,9,16
A	column 2, line 52 -column 3, line 42 column 6, line 6 -column 7, line 12 column 17, line 9 -column 18, line 4 column 24, line 10-64 --- -/--	2-7, 10-15

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 August 2002	21/08/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Correia Martins, F

national Application No
PCT/GB 02/01347

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 437 050 A (LAMB ROBERT G ET AL) 25 July 1995 (1995-07-25)	1,8,9,16
A	column 2, line 35 -column 3, line 42	2-7, 10-15
	column 5, line 14-32 column 8, line 3-64	

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

national Application No
PCT/GB 02/01347

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 0111496	A	15-02-2001	AU	6456800 A	05-03-2001
			WO	0111496 A2	15-02-2001
US 5918223	A	29-06-1999	NONE		
US 5437050	A	25-07-1995	NONE		

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